Aircraft Noise:

How We Measure It and Assess Its Impact

U.S. Department of Transportation
Federal Aviation Administration

AIRCRAFT NOISE:

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NOISE – UNWANTED SOUND

Noise is usually regarded as unwanted sound – sound that disturbs our routine activities or peace and quiet, and perhaps causes a feeling of annoyance. Which sounds are NOISE is obvious to each listener, and he or she has no need to measure it. It's there, and it's bothersome.

But those who work to abate noise, to minimize its effects, or to develop quieter vehicles, need to measure noise. And that is not an easy task. Consider sounds typical of a suburban neighborhood on a "quiet" afternoon. If a short time history of those sounds is plotted on a graph, it would look very much like Figure 1.

The sound levels are plotted in units of A-weighted decibels (abbreviated dB, or sometimes dBA), a logarithmic measure of the magnitude of a sound as the average person hears it. The "A-weighting" accounts for the fact that humans do not hear low frequencies and high frequencies as well as they hear middle frequencies, and it corrects for the relative efficiency of the human ear at the different frequencies. A logorithmic measure is used in order to cover efficiently the wide range of sound magnitudes encountered daily.

In this example, the background, or residual sound level in the absence of any identifiable noise sources, is about 45 dB. During roughly three-quarters of the time, the sound level is 50 dB or less. The highest sound level, caused by a nearby motorcycle, is 73 dB, while an aircraft generates a maximum sound level of about 68 dB. The question then becomes: how do we "measure" this variable community noise?

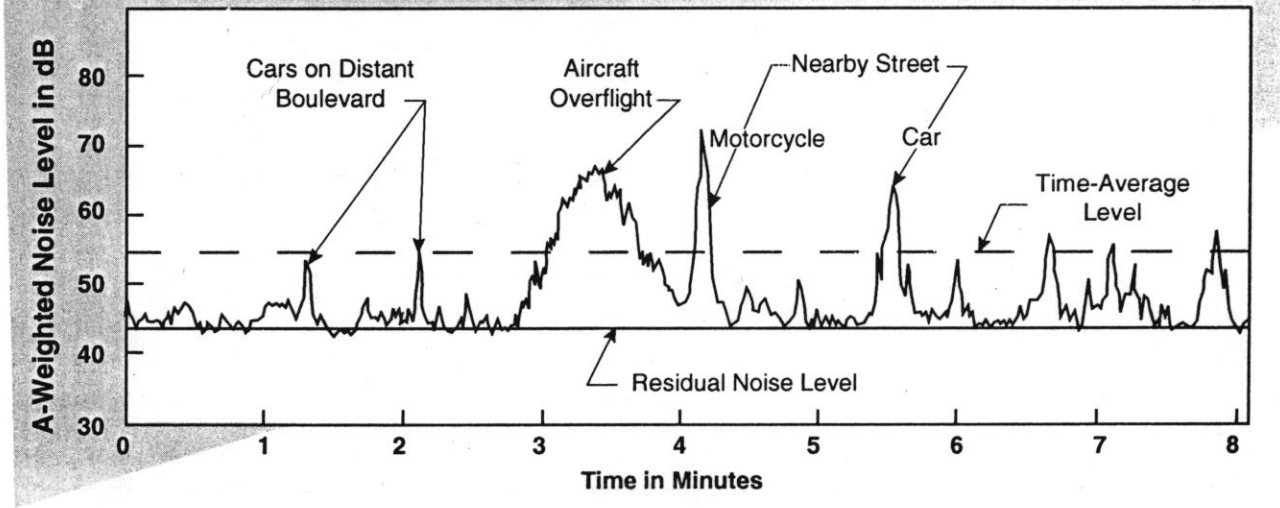
MAXIMUM SOUND LEVEL

One obvious way of describing this sound environment is to measure the maximum sound level – in this case, the nearby motorcycle at 73 dB. But the aircraft sound, although not as loud as the motorcycle, lasts longer. Studies have shown that human response to noise involves both the maximum level and its duration, so the maximum sound level alone is not sufficient to evaluate the effect of noise on people.

SOUND EXPOSURE LEVEL

A second way of describing this sound environment is to measure the sound exposure level (abbreviated SEL), which is the total sound energy of a single sound event and takes into account both its intensity and duration. One way to understand SEL is to think of it as the sound level you would experience if all of the sound energy of a sound event occurred in one second. This normalization to a duration of one second allows the direct comparison of sounds of different durations. In the sample time history in Figure 1, the motorcycle generates an SEL of about 77 dB, while the aircraft generates an SEL of about 81 dB.

Figure 1



EQUIVALENT SOUND LEVEL

The maximum sound levels and sound exposure levels measure individual sound events that may occur only once, or may occur several times during the day in our neighborhood. The number of times these events occur is also important in measuring the noise environment. One way to describe this factor might be to count the number of events per day for which the SELs exceed 80 dB, plus the number which exceed 75 dB, plus the number which exceed 70 dB, and so on. A more efficient way to describe both the number of such events and the sound exposure level of each is the time-average of the total sound energy over a specified period, referred to as the equivalent sound level (symbolized Leq). In the example shown in Figure 1, the time-average sound level is roughly 56 dB. This accounts for all of the sound energy during the sample period, and provides a single-number descriptor in terms of sound energy per second.

DAY-NIGHT AVERAGE SOUND LEVEL

One additional factor is also important in "measuring" a sound environment – the occurrence of sound events during nighttime. People are normally more sensitive to intrusive sound events at night, and the background sound levels are normally lower at night because of decreased human activity. Therefore a "penalty" may be added to sound levels which occur during night hours, to include these factors. By convention, a 10 dB penalty is added to sound levels occurring between 10:00 p.m. and 7:00 a.m. the following morning. The 24-hour average sound level, including this 10 dB penalty, is known as the day-night average sound level (abbreviated DNL). This 10 dB penalty means that one nighttime sound event is equivalent to 10 daytime events of the same level.

COMMUNITY ANNOYANCE

Annoyance is a summary measure of the general, adverse reactions of people to noises which disrupt their daily activities – telephone conversations, TV/radio listening, sleep, or simple tranquility. Currently, the best measure of this reaction is the percentage of people who characterize themselves as "highly annoyed" by long-term exposure to their noise environments.

Extensive research has found that day-night average sound level correlates very well with community annoyance from most environmental noise sources. Figure 2 summarizes the relationship between DNL and percentage of people who said they were highly annoyed by transportation noise, based on 453 surveys conducted worldwide. Some of these studies found that communities report themselves slightly more annoyed by aircraft noise than by surface transportation noises.

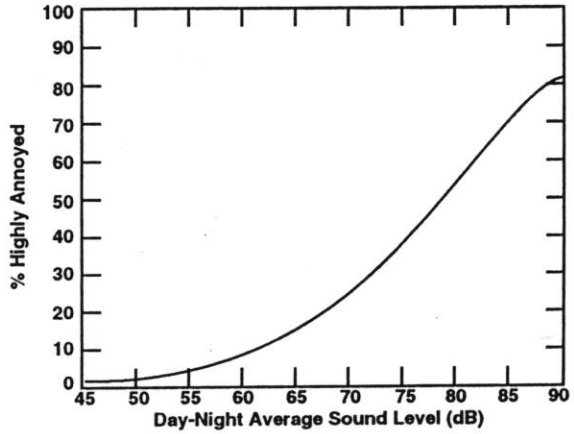
NOISE COMPATIBILITY GUIDELINES

Using this research, federal agencies have adopted certain guidelines for compatible land uses and environmental sound levels. Land use is normally determined by property zoning, such as residential, industrial, or commercial. Noise levels that are unacceptable for homes may be quite acceptable for stores or factories. The Federal Aviation Administration has issued these guidelines as part of its Airport Noise Compatibility Program, found in Part 150 of the Federal Aviation Regulations.

In general, most land uses are considered to be compatible with DNLs that do not exceed 65 dB, although Part 150 declares that "acceptable" sound levels should be subject to local conditions and community decisions. Nevertheless, a DNL of 65 dB is generally identified as the threshold level of aviation noise, and other sources of community noise, which are "significant."

In adopting a threshold criterion for noise impact, we must keep several important factors in mind. First, a day-night average sound level below 65 dB does not mean that no one is annoyed by that level of noise from transportation sources. To the contrary, as shown in Figure 2, about 12 percent of people living with a DNL of 65 dB report themselves to be "highly annoyed". About 3 percent are highly annoyed at a DNL of 55 dB. This is understandable, because the same research on noise effects has found that the physical amount of noise is only one element in feelings of annoyance with environmental noise. Activities which may be disrupted by noise events (study, conversation, listening to music, watching TV, solitude, etc.); beliefs that such noise could be better controlled; attitudes toward the noise maker; and personal fears regarding the source of the noise, are all important factors in people's perception of annoyance. Additionally, a small percentage of people are simply more sensitive to noise than most other people, which a small percentage are little annoyed even at high noise levels. The combination of these factors causes different people to interpret sounds as "unwanted" noise in different ways. A measure of noise impact, such as day-night average sound level, provides a reliable indicator of overall community response, but does not tell how any single individual will respond.

FIGURE 2



As a result, there is probably no minimum level of transportation noise at which no one is annoyed. General guidelines for noise compatibility identify day-night average sound levels between 55 and 65 dB as "moderate exposure" and as generally acceptable for residential use. Above a DNL of 65 dB, these guidelines identify the noise impact as "significant", and this designation is currently a factor in decisions to provide federal funds for mitigation projects.

Because DNL combines both the intensity and number of single noise events (along with nighttime weighting), it also is not a good estimator of the single-event sound levels which are experienced. For example, a DNL of 65 dB may be generated by any of the following combinations of average sound exposure level and the effective number of those events, where "effective" number is the sum of the number of daytime events plus 10 times the number of nighttime events:

Average SEL	Effective Number of Events	DNL
87.4 dB	500	65 dB
94.4 dB	100	65 dB
97.4 dB	50	65 dB

Consider two communities: one near a large airport, the other near a small one. Both are exposed to a DNL of 65 dB. Although people near the small airport experience only 50 aircraft operations in a day, the average SEL of each of these is about 97 dB. On the other hand, the community near the large airport is impacted by 500 daily operations, but each of these as an average SEL of about 87 dB. This does not invalidate the usefulness of the DNL measure, but should be considered, for example, in determining needs for structural sound insulation.

Some criticism of DNL stems from beliefs that the levels identified with land-use compatibility are too high. Any compatibility guideline, such as a DNL of 65 dB, must represent a balance between that level which is most desirable to protect communities and that which can be achieved with cost-effective mitigation measures and available technology. There is no single criterion which can fit all airports and all communities. Local communities may choose to mitigate impacts below a DNL of 65 dB.

SUPPLEMENTAL MEASURES

A time-average measure of noise impact, such as day-night average sound level, is also criticized because people feel that they are annoyed by individual sound events, rather than some "fictitious" average level. Clearly, people are bothered by individual noise events, but their sense of annoyance increases with the number of those noise events, and those which occur late at night.

DNL provides a combined "measure" of these factors which can be used to evaluate existing and predicted future conditions on an unambiguous, single-number basis. Other measures, such as maximum sound level, or sound exposure level, give valuable supplemental information in analyzing airport noise. For example, as noted above, in designing sound insulation for dwellings and schools, single-event measures are necessary. Nevertheless, day-night average sound level remains the best single measure for assessing the effects of airport noise on communities, and allows a standardized and effective means for measuring transportation noise.

FOR MORE INFORMATION

- "Federal Agency Review of Selected Airport Noise Analysis Issues", Federal Interagency Committee on Noise, August 1992.
- "Updating a Dosage-Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise", J.Ac.Soc.Am., 89, 221-233 (January 1991).
- "Aviation Noise Effects", Report FAA-EE-85-2, March 1985.
- "Guidelines for Considering Noise in Land-Use Planning and Control", Federal Interagency Committee on Urban Noise, June 1980.
- "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety", U.S. Environmental Protection Agency, March 1974.

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